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Water Control

Estimation of Irrigation Water Values In Western Oklahoma

by

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FOREWORD

This report presents the major findings of one phase of a program of economic investigations of upstream watershed development in the Washita River Basin of Oklahoma. The overall program is a cooperative undertaking between the Economic Research Service, United States Department of Agriculture, and the Oklahoma Agricultural Experiment Station. The Soil Conservation Service of the United States Department of Agriculture has also cooperated in the overall program by providing funds through an agreement with the Economic Research Service.

The basic data and the programming analysis presented herein came from Dale O. Anderson's unpublished Ph.D. dissertation, "The Value of Irrigation Water in the Washita River Basin of Roger Mills County, Oklahoma," Oklahoma State University, May, 1965. It was done under Oklahoma Agricultural Experiment Station Project 1041, "Economics of Agricultural Land and Water Use, Conservation, and Development in Watersheds of Oklahoma." However, the irrigation budgets developed for the dissertation have since been revised and updated.* The major revisions were increased fertilizer applications at higher levels of water application and adjustments in sorghum yields. The revised budget data might influence the values for irrigation water presented in this bulletin, but the effect would be negligible.

The authors appreciate the guidance and advice of Dr. W. B. Back, now with NRED, ERS, Washington, in the formative stages of this study.

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*Dale O. Anderson, Neil R. Cook, and Daniel D. Badger, Irrigated Crops on Bottomland Soils of Western Oklahoma: Costs and Returns, Okla. Agri. Expt. Sta., Processed Series P-521 (Stillwater, 1965).

Dr. James S. Plaxico and Dr. Odell L. Walker also provided much encouragement and valuable criticisms of this research project. The constructive comments by Dr. Vernon Eidman were appreciated. We also wish to express our appreciation to the personnel of the Soil Conservation Service, USDA, and to the farmers in the Roger Mills County area, whose assistance made this study possible.

SUMMARY

This study was made to determine the value of water used to irrigate crops and pastures and to estimate the optimum allocation of alternative levels of available water among crops in Western Oklahoma. A linear programming analysis was made of typical farms to study the effects of different variables on the value of water. Alternative crop systems, farm resource situations, systems of farming, rainfall conditions, and rates of water application were analyzed.

Dryland situations were programmed first to serve as a base from which to measure the value of irrigation for each of three assumed farm water levels. The programming activities included dryland and irrigated crop activities as well as alternative beef and dairy enterprises.

In general, the optimum level of irrigation for most crops was at the high level of water application. Even at very limited levels of water supply, it was more profitable to irrigate fewer acres rather than more acres. Programmed land use on any particular farm depended upon the proportions of floodplain land and other bottomland as well as the basic acreage allotments for cotton and wheat.

Increasing the quantity of water available did not increase the number of beef cows appearing in the optimum farm organization. Although irrigation had no effect on number of dairy cows for average rainfall conditions, irrigation did increase the number of dairy cows on each of the resource situations which included dairy for below average rainfall conditions. Irrigation increased the number of feeder cattle more than any other livestock considered in the study. The number of feeder cattle

appearing in the programmed optimum varied directly with the supply of irrigation water available.

Total labor and capital requirements and net farm income increased for all farms as water supply per farm increased. The increase in annual labor requirements was about seven hours per irrigated acre. When the optimum amount of water was available, the increased nonland capital requirements amounted to about $57 per irrigated acre. About 1.4 acre-feet of water was required for each acre of bottomland irrigated and each acre-foot of water available at the farm gate was worth about $7.30 (after all variable inputs including the additional family labor had been compensated.) This is equivalent to about $10.15 per irrigated acre.

Each of the above figures varied among farm resource situations and rainfall conditions. Several of the farms could afford to pay more than $7.30 per acre-foot. Others could not afford to pay that much. Under below average rainfall conditions, the value of water was much greater than $7.30 per acre-foot for most farm situations and farm water levels. These high values per acre-foot would of course be balanced by the low values during years of above average rainfall.

The average value of water stored in the upstream floodwater detention structures in the County would be less than $7.30 per acre-foot because of costs of conveyance from the structure to the irrigable land and because of evaporation and seepage loss before final use. Water may be particularly valuable for farms strategically located relative to the reservoirs. This locational factor would need to be considered if water were to be allocated among farms on the basis of its value to the farm.

ESTIMATION OF IRRIGATION WATER VALUES IN WESTERN OKLAHOMA

by

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Technological advances in agriculture have been rapid in recent years. Improved varieties of crops have been developed. Machinery has been devised to better till the soil and control weeds. Mineral and organic fertilizers have been produced to supplement soil resources. Insects and diseases are being brought under control.

Although these technological developments have helped reduce instability of production, agricultural production and incomes in the Great Plains States are still highly variable. A substantial amount of this income variability is generated by highly variable yields arising from extreme seasonal and annual fluctuations in quantity and distribution of rainfall.

Irrigated agriculture generally permits greater control of physical resources than do dryland systems of farming. Since moisture is a very crucial variable in agricultural production, irrigation could be expected to add substantially to the stabilization of production and income.

Research reported herein was made to determine the value of water used to irrigate crops and pastures and to estimate the optimum allocation of alternative levels of available water among crops. Alternative

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crop systems, farm resource situations and systems of farming within a given resource situation were analyzed.

AREA OF STUDY

This study is concerned with the bottomland soils of Roger Mills County in western Oklahoma. Farming, ranching, and associated agricultural enterprises provide the base for the economy of Roger Mills County. Wheat and cotton are the major crop enterprises, and a beef cow-calf system is the leading livestock enterprise.

Roger Mills County in western Oklahoma is typical of the high risk Great Plains area. Figure 1 summarizes the average annual yields per acre for cotton, grain sorghum and wheat from 1947 to 1964. These yield data indicate the wide annual fluctuations in yields and, consequently, the technical uncertainty a farmer faces when planning the allocation of his resources.

The average annual precipitation in the county is approximately 24 inches (1), but rainfall is highly erratic. Since 1914 annual precipitation has varied from 13 to 46 inches. Droughts of from three to eight weeks occur during nearly all growing seasons. These droughts are usually accompanied by hot, dry, evaporative winds, which quickly dissipate the soil moisture supplies. Interspersed with such droughts are storm periods, very frequently violent and of short duration, which produce intense rainfall and possible flooding over small areas.

Many flood detention structures have been built in Roger Mills County in connection with the upstream watershed program of the Soil Conservation Service. The intended purpose of the program has been to reduce soil erosion, water run-off and damaging floods, but the

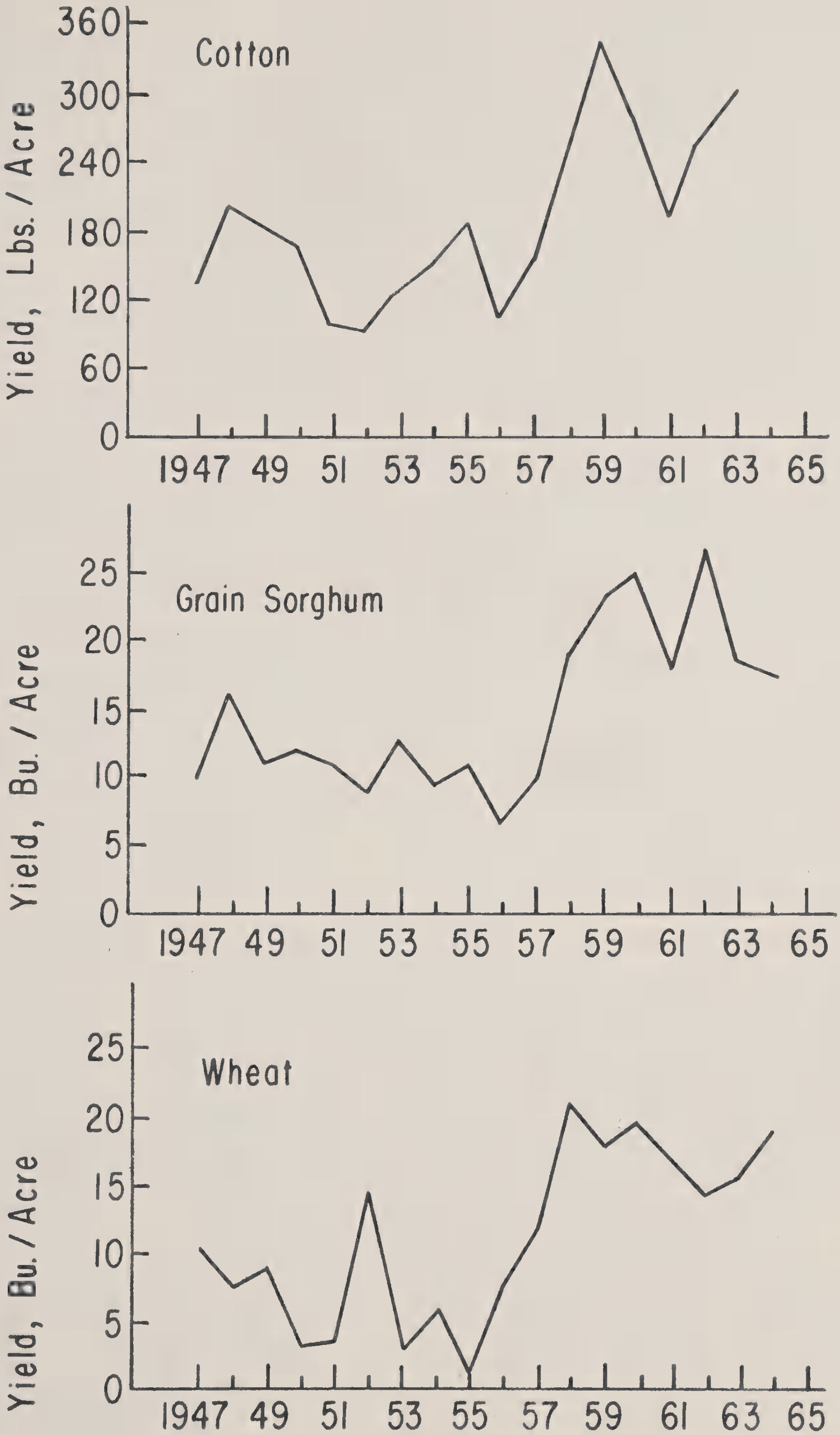

Figure 1. Average Annual Yields for Cotton, Grain Sorghum, and Wheat, 1947-1964, Roger Mills County, Oklahoma.

Source: Oklahoma Crop and Livestock Reporting Service, Oklahoma City, Oklahoma.

impounded water provides a potential irrigation supply. The lack of information concerning required capital and labor resources and potential increases in income may be the reason for the slow adaptation of irrigation from these surface structures.

METHOD OF ANALYSIS

Basic Theoretical Framework

Allocation of a scarce resource, such as water, is optimum when its marginal value product is equal among all competing uses.[1] In this study, the marginal value product of irrigation water was equated among all the competing uses on a given farm. The marginal value products of water were not equated among farm situations within the county. However, the results of this study would facilitate such a task, if an institutional arrangement were available to allocate water among farms on the basis of its marginal value product.

Assumptions

The more important assumptions for this analysis were: (1) a fixed acreage of potentially irrigable land exists for each resource situation under study; (2) all land in a given productivity class with potential for irrigation is equally productive; (3) farm programs restrict the acreage of wheat and cotton in the organization; (4) individual farmers can purchase any quantity of needed resources, except land and family labor, at a specified price; (5) all products, except forage sorghum and

[1]This is the necessary condition for profit maximization. The second order or sufficient condition for profit maximization is that the marginal value product of water must decline as additional water is applied.

pastures, can be sold at a specified price; and (6) knowledge and management capabilities among farmers are equal.

Linear programming was used to determine optimum farm organizations for one dryland and three irrigated programming models. Each of the models assumed a different level of water availability per farm. The dryland optimum farm organization was used as the base for computing and analyzing returns to alternative levels of water availability for each resource situation.

The typical whole farm approach was used as the basic unit of analysis. This approach considers decisions of the entire farm rather than limiting the scope of analysis to the portion of the farm containing only potentially irrigable land. Also, it is possible to analyze changes which take place on the bottomland as well as to analyze shifts in land use between upland and bottomland, as a result of irrigation.

The amortized value of the irrigation equipment was treated as a variable cost because of the long run nature of the decisions involved. This procedure recognizes the substitution possibilities between irrigation equipment and other forms of capital in making long-run decisions on whether to invest in irrigation systems. Investments in irrigation equipment as well as in systems for water conveyance depend on their profitability over a long period of time. Once a system is purchased, however, equipment costs become "fixed" and do not influence optimum water application rates or other operational decisions. The problem in this study was to investigate the feasibility of investment as well as to determine optimum rates or irrigation, in which case capital costs for equipment were considered a "variable" in the analysis.

Costs of storing water and conveying water to the farm have not been considered in this analysis because of the high degree of variation of such costs among different farm situations.

Sources of Data

Many of the basic data required for the programming analysis were obtained by interviewing a sample of 65 farmers in 1961. The population from which the sample was chosen was 150 farm units containing bottomland in the Washita River Basin of Roger Mills County.

Information obtained from this survey included an inventory of land resources, the land use pattern of previous years, present and historical dryland yields of frequently grown crops, and an inventory of livestock, crop and livestock machinery, and dairy equipment. From the few farmers in the sample who had irrigation experience, information was obtained on present and historical irrigated yields, investment in irrigation equipment and cultural practices unique to irrigation farming.

Data obtained from the farm survey were supplemented with data from secondary sources developed from other western Oklahoma studies (2) and (3). Unpublished information and experience of Oklahoma State University staff members and Soil Conservation Service personnel also were used extensively.

Typical Farms

The land resource inventory taken in the farm survey provided a basis for stratifying the 65 farms of the survey into six typical farms for programming purposes. The average acres of various classes of cropland and rangeland for the six typical farms are shown in Table 1.

Type of farming was hypothesized as being influential in explaining returns to irrigation water. Important considerations are the efficiency with which the irrigation input is transformed into output, the capacity of crops for utilizing water and the availability of product markets. The classification found in Table 2 most nearly reflects the types of farming found in the Washita River Basin of Roger Mills County.

Rainfall Conditions

To evaluate the effect of rainfall on the demand for irrigation water and changes in net farm income, rainfall (1) conditions were classified into three distinguishable categories: (1) 10 years with a below-average annual rainfall of 16.8 inches, (2) 26 years with an average annual rainfall of 23.8 inches, and (3) 10 years with an above-average annual rainfall conditions and in lesser detail for below average rainfall.[2] A preliminary analysis of irrigation under above average rainfall conditions indicated that it was not profitable; thus, it was excluded from the programming analysis.

Crop Irrigation Levels

Three crop irrigation levels were designed to estimate the most profitable rate of irrigation. The quantity of water needed at the high irrigation level for each crop was determined by the water requirement

[2] The analysis of irrigation under below average rainfall conditions is somewhat artificial because abnormal rainfall years cannot be forecast far enough in advance for individual farmers to make major adjustments in organization.

TABLE 1: DISTRIBUTION OF LAND RESOURCES BY PRODUCTIVITY CLASS FOR SIX TYPICAL FARMS

Land Classes*	Typical Farm A	B	C	D	E	F
Cropland						
L_1	7	25	8	75	13	155
L_2	31	60	57	88	99	147
L_3	13	1	10	11	19	159
L_4	29	17	173	62	190	76
Total	80	103	248	236	321	537
Rangeland						
L_5	8	8	11	28	38	78
L_6	115	211	378	316	1,244	944
L_7	73	56	17	9	131	1,077
Total	196	275	406	353	1,413	2,099
Total Acres in Farm	276	378	654	589	1,734	2,636

*Land classes are defined in Appendix Table 1. L_1, L_2, and L_5 represent bottomland soils of decreasing productivity, and L_3, L_4, L_6, and L_7 represent upland soils of decreasing productivity. Estimated bottomland yields are given in Appendix Table II.

TABLE 2: CLASSIFICATION OF TYPICAL FARMS BY TYPES OF FARMING

Farm Size and Type*	Description of Farm Type
A-1	Small grains-cotton-cow calf
B-1	Small grains-cotton-cow calf
C-1	Small grains-cotton-cow calf
C-2	Wheat-cotton-dairy
D-1	Small grains-cotton-cow calf
D-2	Wheat-cotton-dairy
E-1	Small grains-cotton-cow calf
E-2	Wheat-cotton-dairy
F-1	Small grains-cotton-cow calf
F-2	Small grains-cotton-cow calf-buy sell

*This designation of farm size and type will be used throughout the study.

of the crop and the expected rainfall.[3] The water requirement for each crop was computed from basic climatological data for Roger Mills County utilizing a method developed by Blaney and Criddle (3). This procedure was used to estimate total water requirements for crops consistent with optimum plant growth in relation to climatic factors in Roger Mills County.

The water requirement for the high irrigation level for each crop (I_3 in Table 3) is the difference between the computed total water requirements and the moisture available from natural precipitation.

Irrigation levels I_1 and I_2 in Table 3 were selected because experimental data for these levels of application were available. Yields consistent with the various irrigation levels were based on results at the Altus Irrigation Experiment Station in Southwestern Oklahoma through 1960. Soil scientists at Oklahoma State University, personnel of the Soil Conservation Service, and local agricultural workers in the area were consulted before final yield estimates were made (Appendix Table II).

<u>Farm Water Levels</u>

The quantity of water available per farm was assumed at four levels. The first level programmed was an unlimited supply indicated as farm

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[3] Expected rainfall refers to normal rainfall received during growing season of March-September for all crops except wheat. For wheat, the growing season is assumed to be August-May. The expected rainfall for the March-September period is 14 inches during below average rainfall years and 19 inches during average rainfall years. Expected rainfall for the August-May period is 12 inches during below average rainfall years and 17 inches during average rainfall years.

TABLE 3: CROP IRRIGATION LEVELS, IRRIGATION WATER APPLIED, AND WATER AVAILABLE BY CROP, AVERAGE AND BELOW AVERAGE RAINFALL

Crop	Levels of Irrigation*	Irrigation Water Applied Average Rainfall	Irrigation Water Applied Below Average Rainfall	Rainfall During Growing Season Average Rainfall	Rainfall During Growing Season Below Average Rainfall	Total Water** Available
		Inches				
Cotton	I_1	6	11	19	14	25
	I_2	13	18	19	14	32
	I_3	20	25	19	14	39+
Wheat	I_1	5	10++	17	12	22
	I_2	10	15	17	12	27
	I_3	15	20	17	12	32+
Alfalfa	I_1	6	11++	19	14	25
	I_2	12	17	19	14	31
	I_3	18	23	19	14	37+
Grain and Forage Sorghum	I_1	4	9++	19	14	23
	I_2	7	12	19	14	26
	I_3	10	15	19	14	29+
Midland Bermuda	I_3	16	21++	19	14	35+

*Dryland conditions for each crop were represented by I_0.

**These figures represent natural precipitation during growing season plus irrigation water applied.

+These figures represent total water requirements consistent with optimum plant growth. Surface evaporation and other economically unavoidable wastes are included.

++These figures represent enough irrigation water to replace the deficit between average and below average rainfall seasons plus irrigation water applied in seasons of average rainfall.

water level 4.[4] Farm water levels 2 and 3 were set at one-third and two-thirds, respectively, of farm water level 4. Farm water level 1 was programmed as a dryland situation for each typical farm and rainfall condition.

Method of Irrigation

Sprinkler irrigation was assumed throughout the study. The investment requirements in irrigation equipment were based on two basic sizes with combinations of these two making up five irrigation systems (Table 4). The total investment in irrigation equipment, including pump, motor, pipe, sprinklers, etc., ranged from $3561 for the small system irrigating approximately 50 acres to $19,600 for a system designed to irrigate about 300 acres during periods of peak water requirements. The annual costs of irrigation equipment per acre are nearly constant. To facilitate programming, annual costs of irrigation equipment were assumed to be $8.06 per acre for all crops and all farm sizes. If fewer acres were irrigated than the system was designed to handle, the additional annual equipment cost was deducted from net farm income before computing the value of water.

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[4]Farm water level 4 represents the quantity of water required for each farm situation and for each rainfall condition to satisfy the following equilibrium condition:

$$\frac{MVP_{w1}}{MFC} \quad \frac{MVP_{w2}}{MFC} = \quad \ldots \quad = \frac{MVP_{w6}}{MFC} = 1$$

where $MVP_{w1} \ldots MVP_{w6}$ represents the marginal value products of water in the production of 6 products and MFC is the marginal factor cost of applying water.

TABLE 4: ESTIMATED TOTAL INVESTMENT AND ANNUAL COSTS OF IRRIGATION SYSTEMS DESIGNED FOR TYPICAL FARMS IN THIS STUDY*

Items	Size of Irrigation System 50 Acres	100 Acres	150 Acres	200 Acres	300 Acres
	- Dollars -				
Investment					
Pump and Motor	1,470	2,400	3,870	4,800	7,000
Pipe, Mainline	512	1,452	1,964	2,904	3,900
Pipe, Laterals	1,248	2,112	3,360	4,224	6,600
Sprinklers	252	594	846	1,188	1,650
Risers	29	50	79	100	150
Miscellaneous Items	50	100	150	200	300
Total Investment	3,561	6,708	10,269	13,416	19,600
Salvage Value**	356	671	1,027	1,342	1,960
Average Annual Investment	1,958	3,689	5,648	7,379	10,780
Annual Cost:					
Depreciation †	247	464	711	929	1,357
Taxes and Insurance	39	74	113	148	216
Interest † †	117	221	339	443	647
Total	403	759	1,163	1,520	2,220
Annual Cost per Acre	8.06	7.59	7.75	7.60	7.40

*Staff members of the Department of Agricultural Engineering, Oklahoma State University, provided technical assistance in designing the irrigation systems.

**Assumed to be 10 per cent of total investment.

†Annual depreciation $= \dfrac{\text{total investment - salvage value}}{13}$

† † Interest on investment computed as six percent of average annual investment.

PROGRAMMING RESULTS

The potential changes in farm organization, resource requirements and income that could occur if irrigation were adopted are discussed in this section. Programmed dryland situations (farm water level 1) serve as a base from which the changes in farm organization, resource requirements, and income due to various assumed water availabilities (farm water levels 2, 3, and 4) can be measured.

Changes in Farm Organization

Very little shifting of crops from upland to bottomland was attributable to changes in irrigation levels. Crops grown on upland under dryland conditions generally remained on these land classes as available irrigation water increased, farm size increased, or farm type varied. The major changes in land use as a result of alternative irrigation levels were between bottomland classes L_1 and L_2. The relatively low producing upland classes L_3 and L_4 were used to produce feed grains, mainly utilized on the farms, and wheat.

In general, the optimum level of irrigation for most crops was at the high level of water application (I_3). Even at very limited levels of water supply, it was more profitable to irrigate fewer acres at the highest crop water level than to irrigate more acres at a lower level.[5] However, when below average rainfall conditions were considered, the optimum levels of irrigation for wheat and grain sorghum were at lower levels of water application per acre.

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[5]Inclusion of the annual costs of irrigation equipment in the enterprise production expenses associated with each level of irrigation may have been responsible for this conclusion (See Assumptions on pages 4 and 5)

In general, cotton and alfalfa were the first crops to be irrigated under limited water supplies. Alfalfa was the first crop to be irrigated on farms where the farm use value of alfalfa was higher than the market value. Considerably more forage crops were produced and irrigated on resource situations where a dairy enterprise substituted for a beef cow-calf enterprise on the same basic resource situation.

Increasing the quantity of water available for irrigation did not increase the number of cows included in the optimum farm organization for any resource situation. However, there were resource situations where spring calving enterprises were decreased and fall calving enterprises increased as irrigation water available to the farm increased. This shift resulted from competition for spring labor between irrigated crops and a spring calving cow-calf enterprise.

Although irrigated grazing activities were included in the programming model, these activities were never feasible in any of the optimum farm plans. Thus, the returns from irrigated grazing enterprises were low relative to other land using production alternatives.

Increasing water availability had little effect on the size of the dairy herd but did have some effect on the number of feeder cattle in the optimum farm organization. This occurred because the basic feed requirement of feeder cattle was alfalfa, sorghum and other forages which were included as irrigated activities. The number of feeder cattle in a final optimum farm organization was directly related to the availability of irrigation water.

Changes in Resource Requirements

Labor. A total of 2,398 hours of operator and family labor per year was available at no out of pocket cost to each of the farm situations.

Additional labor was assumed available at $1.00 per hour. In many of the small farm situations a portion of the operator and family labor was not employed even at the high level of irrigation (Table 5). On farm situation F-2, the family labor used decreased when the first levels of irrigation were applied while hired labor increased. The hired labor was needed during seasons of the year in which the family labor was fully employed, but not as much family labor was required during other seasons because of a small change in the farm organization. The increase of 2,249 hours of hired labor and 331 hours of family labor on farm F-2, farm water level 4, is equivalent to about one man-year or about two hired men during the irrigation season. For the entire population of farms, about 54 percent more labor is required for irrigation level 4 than for dryland farming for average rainfall conditions. About 65 percent more labor is required for below average rainfall than under dryland conditions and average rainfall.

The increases in total labor requirements with various levels of irrigation, on a per irrigated acre basis, are presented in Table 6. The averages for the entire county are very similar for each farm water level. Size of farm had little influence on the increased labor required per irrigated acre in spite of the fact that most of the additional labor on the large farms had to be hired at $1.00 per hour.

Nonland Capital. A charge of six percent was assumed for all nonland capital. The changes in nonland capital required as a result of irrigation are presented in Table 7. The figures represent the average annual investment in irrigation equipment plus the changes in nonland

TABLE 5: ANNUAL LABOR REQUIREMENTS FOR DRYLAND OPERATIONS AND CHANGES IN LABOR FROM DRYLAND TO OTHER FARM WATER LEVELS; AVERAGE RAINFALL CONDITIONS

Farm Resource Situation	Annual Labor Dryland Farm Water Level 1			Changes in Labor Due to Irrigation Farm Water Levels								
				2			3			4		
	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total
	Hours											
A-1	0	377	377	0	112	112	0	226	226	0	330	330
B-1	0	523	523	0	241	241	0	579	579	0	811	811
C-1	0	1,027	1,027	0	480	480	0	554	554	0	745	745
C-2	313	2,377	2,690	34	21	55	81	21	102	246	21	267
D-1	0	1,044	1,044	0	380	380	70	805	875	283	911	1,194
D-2	364	2,398	2,762	519	0	519	879	0	879	1,144	0	1,144
E-1	92	1,676	1,768	35	27	62	198	216	414	342	302	644
E-2	4,114	2,398	6,512	258	0	258	594	0	594	856	0	856
F-1	462	2,362	2,824	646	-268	378	1,423	-209	1,214	1,969	10	1,979
F-2	499	2,067	2,566	716	233	949	1,499	331	1,830	2,249	331	2,580

TABLE 6: INCREASES IN ANNUAL LABOR REQUIRED PER IRRIGATED ACRE FROM DRYLAND TO OTHER FARM WATER LEVELS; AVERAGE RAINFALL CONDITIONS

Farm Resource Situation	Farm Water Levels 2	3	4
	Hours		
A-1	9.33	8.69	8.68
B-1	9.27	10.16	9.54
C-1	24.00	12.59	11.49
C-2	2.50	2.43	4.11
D-1	5.59	7.29	7.33
D-2	9.98	8.45	7.02
E-1	1.82	5.67	5.75
E-2	7.59	8.25	7.64
F-1	4.11	6.38	6.55
F-2	9.49	8.76	8.54
Weighted Average*	6.59	7.47	7.35

*Weights are the product of the number of farms in the county within each resource strata and the areas irrigated on each farm resource situation (Appendix Table III).

TABLE 7: NONLAND CAPITAL REQUIRED PER FARM FOR DRYLAND OPERATIONS AND INCREASES IN NONLAND CAPITAL PER FARM AND PER IRRIGATED ACRE FROM DRYLAND TO OTHER FARM WATER LEVELS; AVERAGE RAINFALL CONDITIONS

Farm Resource Situation	Nonland Capital Dryland Farm Water Level 1	Farm Water Levels					
		2		3		4	
	per farm	per farm	per irrigated acre	per farm	per irrigated acre	per farm	per irrigated acre
	Dollars						
A-1	3,150	1,890	157.50	2,147	82.58	2,536	66.74
B-1	4,494	4,062	156.23	4,495	78.86	5,456	64.19
C-1	8,442	2,400	120.00	3,016	68.54	3,585	55.15
C-2	19,985	1,889	85.86	2,031	48.36	2,620	40.31
D-1	8,570	7,736	113.76	9,393	78.28	10,815	66.35
D-2	20,190	7,886	151.65	8,718	83.83	10,310	63.25
E-1	20,190	4,235	124.55	4,943	67.71	5,670	50.63
E-2	69,310	2,705	79.56	3,740	51.94	4,340	38.75
F-1	30,010	12,990	141.20	15,835	83.34	17,765	58.82
F-2	44,510	6,060	60.60	10,755	51.46	12,115	40.12
Weighted Average*			123.64		73.98		57.15

*Weights are the product of the number of farms in the county within each resource strata and the acres irrigated on each farm resource situation (Appendix Table III).

capital that may occur on the farm as a result of changes in farm organization. The money required to purchase and install an irrigation system is only indirectly related to these figures.

The changes in capital requirements per irrigated acre illustrate the advantage of allocating the cost of the irrigation equipment over more acres. The variation among farm types in the increased capital requirements per acre is a function of the ratios among resources available.

Irrigation Water. Under average rainfall conditions, about 1.4 acre-feet of water is required for each irrigated acre (Table 8). As irrigation water becomes relatively scarce, the acres irrigated decrease and the water applied per acre remains the same. Among farm types, the water applied ranges from 1.12 to 1.62 acre-feet per irrigated acre per year.

Under below average rainfall conditions, the acre-feet of water required per acre is 1.25 for the first level of irrigation (farm water level 2), 1.30 for the second level of irrigation and 1.81 for the high level of irrigation (farm water level 4). As irrigation water becomes limited under below average rainfall conditions, both acres irrigated and water applied per acre decrease. This is very evident on farms where unpaid family labor is scarce (on larger farms). The limited amount of water is allocated to those crops that are more drouth resistant and thus require less water and less labor for irrigation. Irrigated alfalfa is replaced by irrigated wheat and/or grain sorghum. In other words, if below average rainfall and low water availability could be predicted for any particular year, it would pay to plant crops which have low water requirements. Since it is difficult to predict weather conditions for

TABLE 8: ANNUAL IRRIGATION WATER USED PER IRRIGATED ACRE BY FARM WATER LEVEL AND RAINFALL CONDITIONS

Farm Resource Situation	Average Rainfall Farm Water Levels 2	3	4	Below Average Rainfall Farm Water Levels 2	3	4
	Acre Feet					
A-1	1.56	1.44	1.48	2.00	1.26	1.89
B-1	1.60	1.46	1.46	1.77	1.25	1.88
C-1	1.51	1.37	1.39	1.69	1.20	1.80
C-2	1.33	1.40	1.35	1.68	1.51	1.71
D-1	1.12	1.27	1.40	1.04	1.37	1.81
D-2	1.45	1.45	1.39	1.83	1.69	1.79
E-1	1.45	1.35	1.32	1.43	1.20	1.81
E-2	1.47	1.38	1.33	1.58	1.41	1.65
F-1	1.52	1.48	1.39	.99	1.26	1.81
F-2	1.37	1.31	1.36	1.16	1.24	1.78
Weighted Averages*	1.40	1.39	1.39	1.25	1.30	1.81

*Weights are the product of the number of farms in the county within each resource strata and the acres irrigated on each farm resource situation (Appendix Table III).

an upcoming crop year, it is probably better to assume average rainfall conditions when making production decisions.

Changes in Net Farm Income and the Value of Water

Both net farm income per irrigated acre and value of water increased on several farms and for the average of all the farms between farm water levels 2 and 3. The second increment of water (level 3) was worth more than the first (level 2) because of the inefficient use of the irrigation equipment for the first increment of water. Since the irrigation system for a particular resource situation was designed to efficiently irrigate all its irrigable land at farm water level 4, the annual equipment cost per acre was high for the relatively small number of acres irrigated at level 2.

Net Farm Income. Table 9 shows net farm incomes for dryland operations by rainfall conditions. Assuming an unlimited farm water supply (farm water level 4), the increase in net farm income is about $13.47 per irrigated acre (Table 10). Increases in net farm income per irrigated acre are $13.43 under farm water level 3 and $11.44 under farm water level 2. This also assumes that: (1) the additional family labor used is not reimbursed, and (2) the additional nonland capital used is paid six cents per dollar. Since the $13.47 return is consistent with 18,905 acres of irrigable land, the potential increase in net farm income in the county is about $254,650 annually before allowing for costs of storage and conveyance.[6]

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[6]This assumes average rainfall conditions, enough water for farm water level 4, and optimum farm organizations.

TABLE 9: NET FARM INCOME FOR DRYLAND OPERATIONS, BY RAINFALL CONDITIONS, FOR TYPICAL FARM RESOURCE SITUATIONS

Farm Resource Situation	Net Farm Income*	
	Average Rainfall	Below Average Rainfall
	- Dollars -	
A-1	1,767	948
B-1	3,147	1,633
C-1	3,506	1,745
C-2	3,903	2,388
D-1	5,563	2,702
D-2	4,947	3,090
E-1	8,075	4,737
E-2	9,480	5,170
F-1	16,190	9,050
F-2	17,500	10,505

*Net farm income is defined as the returns to land, family and operator labor, and irrigation water.

[illegible]

Depth	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]

TABLE 10: INCREASES IN NET FARM INCOME* PER IRRIGATED ACRE FROM DRYLAND TO OTHER FARM WATER LEVELS BY RAINFALL CONDITIONS

Farm Resource Situation	Average Rainfall			Below Average Rainfall		
	Farm Water Levels			Farm Water Levels		
	2	3	4	2	3	4
	Dollars Per Acre					
A-1	30.92	24.08	21.79	41.75	25.11	28.66
B-1	21.38	19.12	18.04	33.90	23.88	27.59
C-1	19.20	16.91	16.29	22.83	19.25	23.95
C-2	18.41	17.62	14.65	42.05	31.43	27.85
D-1	3.41	10.69	12.62	13.35	18.51	21.58
D-2	17.46	16.69	14.40	21.06	20.69	19.74
E-1	8.24	10.41	10.67	6.45	13.20	16.95
E-2	2.21	6.04	7.23	32.82	22.13	21.37
F-1	7.17	11.23	11.29	12.66	15.18	18.49
F-2	19.65	17.25	15.60	12.95	16.80	20.90
Weighted average**	11.44	13.73	13.47	17.33	18.65	21.52

*Net farm income is defined as the returns to land, family and operator labor, and irrigation water but the increased returns should be imputed to the additional family and operator labor required and to the irrigation water since all other resources either have been paid their market rate, or do not change as a result of irrigation.

**Weights are the product of the number of farms in the county within each resource strata, and the acres irrigated on each farm resource situation (Appendix Table III).

The increases in net farm income per irrigated acre are generally larger under conditions of below average rainfall than they are with average rainfall. It should be remembered, however, that the results of the analysis for below average rainfall conditions would require the farmer to have knowledge of rainfall conditions he will face in a particular year so that he can make adjustments to the situation before it occurs.

The value of water to the farm is usually small under conditions of above average rainfall. Assuming that the above average rainfall conditions balance with the below average rainfall conditions, the values of water determined under average conditions are probably fairly good estimates of the long run returns to the farm from irrigation. As mentioned previously, decisions about investment in irrigation equipment are basically long run in nature and can best be made on assumptions of average rainfall.

Value of Water. When the additional family labor required for irrigation is reimbursed at $1.00 per hour,[7] all other changes in net income can be imputed to the irrigation water. The average values of irrigation water per irrigated acre and per acre-foot of water are shown in Table 11. These values should be interpreted as the value of water to the farm firm after it is delivered to the farm gate. On farms C-1 and D-1, the value of water under farm water level 2 is negative after all additional family labor required has been paid $1.00 per hour. The physical labor of moving pipe in a muddy field may discourage some farmers from making the

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[7]The $1.00 per hour rate is an arbitrary assumption. Some farmers may require a different return to family labor.

TABLE 11: AVERAGE VALUE OF WATER PER IRRIGATED ACRE AND PER ACRE FOOT; AVERAGE RAINFALL CONDITIONS

Farm Resource Situation	Farm Water Level 2		3		4	
	Per Irrigated acre	/acre foot of water	Per Irrigated acre	/acre foot of water	Per Irrigated acre	/acre foot of water
	Dollars					
A-1	21.59	13.81	15.39	10.67	13.11	8.85
B-1	12.11	7.59	8.96	6.16	8.50	5.80
C-1	-4.80	-3.19	4.32	3.16	4.83	3.48
C-2	17.46	13.09	17.12	12.26	14.33	10.58
D-1	-2.18	-1.95	3.98	3.14	7.03	5.03
D-2	17.46	12.01	16.69	11.48	14.40	10.36
E-1	7.45	5.14	7.44	5.52	7.97	6.04
E-2	2.21	1.50	6.04	4.36	7.23	5.42
F-1	10.08	6.62	12.33	8.35	11.26	8.09
F-2	17.32	12.62	15.67	11.93	14.50	10.64
Weighted averages*	8.32	5.94	10.17	7.31	10.14	7.29

*Weights for the values per irrigated acre are the product of the number of farms in the county within each resource strata and the acres irrigated on each farm resource situation (Appendix Table III). Weights for the values per acre foot are the product of the number of farms in the county within each resource strata and the acre-feet of water used on each farm resource situation.

investment in irrigation equipment if they cannot make more than $1.00 per hour. Under the third and fourth farm water levels, the value of water is positive on all farm types and sizes. The weighted averages at the bottom of the table are the values applicable to the entire population of potentially irrigable farms in Roger Mills County.

The average value of the water sorted in the upstream floodwater detention structure would be less than the approximately $7.30 per acre-foot indicated for farm water levels three and four because of conveyance costs from the structure to the irrigable land and because of evaporation and seepage losses. However, the value of water on farms A-1, C-2, D-2, and F-2 is considerably more than the average of approximately $7.30 per acre-foot. The minimum value of water for these four farms is $8.85 per acre-foot. Water may be particularly valuable for farms strategically located relative to the reservoirs. The locational factor would need to be considered if water were to be allocated among farms on the basis of its value to the farm.

Value of Water; Below Average Rainfall Conditions. All assumptions for the value of water under average rainfall conditions hold for its value under below average rainfall conditions. In addition perfect knowledge of weather conditions is also assumed. As expected the value of water is greater for below average rainfall than for average rainfall conditions (Table 12). The value of water is positive for all farm situations. The average value per irrigated acre for all irrigable farms in the county increases as water availability increases, while the value per acre-foot remains nearly the same. However, the smaller farms with unpaid family labor available do not follow the same pattern. As water

TABLE 12: VALUE OF WATER PER IRRIGATED ACRE AND PER ACRE-FOOT OF WATER; BELOW AVERAGE RAINFALL CONDITIONS

Farm Resource Situation	Farm Water Level 2: Per Irrigated Acre	2: Per Acre Foot	3: Per Irrigated Acre	3: Per Acre Foot	4: Per Irrigated Acre	4: Per Acre Foot
	Dollars					
A-1	20.83	10.42	17.66	13.98	18.27	9.64
B-1	24.03	13.56	16.64	13.31	17.41	9.28
C-1	4.00	2.36	12.11	10.11	13.77	7.67
C-2	45.55	27.08	32.35	21.42	28.22	16.52
D-1	7.61	7.32	10.98	8.01	13.95	7.69
D-2	23.18	12.35	20.02	11.84	18.86	10.54
E-1	.32	.22	6.92	5.80	9.84	5.45
E-2	32.82	20.81	22.13	15.65	21.37	12.97
F-1	12.61	12.76	14.48	11.51	17.70	9.80
F-2	11.33	9.80	15.16	12.26	19.32	10.85
Weighted Average*	13.63	10.94	14.80	11.35	17.04	9.44

*Weights for the values per irrigated acre are the product of the number of farms in the county within each resource strata and the areas irrigated on each farm resource situation (Appendix Table III). Weights for the values per acre-foot are the product of the number of farms in the county within each resource strata and the acre-feet of water used on each farm resource situation.

becomes limited on the small farms, a few acres of intensive crops are irrigated at the high crop irrigation levels. As water becomes limited on the larger farms, irrigation water is spread over fewer acres on less intensive crops that require less labor. Thus, the value of water per irrigated acre decreases on many of the small farms and increases on larger farms as water availability increases.

IMPLICATIONS OF RESULTS

The results of this study indicate that irrigation can significantly increase the income from farming in Roger Mills County. However, the availability of a water supply adequate to meet requirements is extremely crucial. Institutional arrangements are needed to facilitate the allocation of the available water. Clarification of the rights that farmers have to water held in floodwater detention structures and to underground water is a necessary first step.

Other factors may also tend to retard the adoption of irrigation. The development of and transition to irrigation agriculture requires additional resource inputs as well as a reallocation of the present resources. Capital is a resource of special concern in this respect. An implied assumption of the programming analysis is perfect knowledge about input-output coefficients, irrigation requirements, prices, farmers' objectives, and managerial ability. Perfect knowledge about necessary factors of production implies a riskless production situation. However, the Great Plains is a high risk agricultural producing region. Risk aversion results in a restriction of the amount of capital invested to a level less than that which is most profitable under a perfect knowledge situation.

The increased labor required for irrigation is another factor that will greatly influence the adoption of irrigation farming in Roger Mills County. Although an adequate annual family labor supply exists on most farms in the area, irrigation requires large amounts of seasonal labor. Since timing of application is very important in attaining maximum profits from irrigation, a dependable labor supply is necessary.

Nevertheless, estimates of the value of irrigation water derived in this study are useful for several purposes. First, they can be used by farmers as a guide for planning the development of and transition to irrigation farming. Second, these estimates provide watershed planners with a basis for: (a) estimating the value of providing additional storage for irrigation on floodwater retarding structures, and (b) designing multiple purpose projects to obtain maximum benefits from available storage sites. Third, these estimates are useful to upstream users in appraising the value of water stored in the local area.

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APPENDIX TABLE I

DEFINITION OF LAND PRODUCTIVITY CLASSES AS USED IN PROGRAMMING ANALYSIS, ROGER MILLS COUNTY

L_1 - Land Productivity Class I. Silty alluvial soil occurring in the flood plains of streams that drain areas of soils that have reddish parent materials of the permian red beds. Norwood Silt Loam.

L_2 - Land Productivity Class II. All bottomland soils with individual units varying from silty alluvial to sandy alluvial soils. Includes both first and second bottom soils. Yahola, Spur and Port, Reinach, and Cass Soils.

L_3 - Land Productivity Class III. Good quality upland. All capable of being cropped. Dill-Quinlan, Miles, Miles-Dill, Holdredge, and Woodward Soils.

L_4 - Land Productivity Class IV. Lower quality upland. Miles, Miles Springer, Springer, Woodward, Pratt, Brownfield-Mobscott Soils.

L_5 - Land Productivity Class V. Bottomland soils subject to frequent flooding. Includes subirrigated range sites. Used exclusively for meadow and pasture. Lincoln and Sweetwater Soils.

L_6 - Land Productivity Class VI. Upland generally not suited for cropping. Brownfield-Nobscot, Pratt Complex, Miles-Nobscot Complex, and Quinlan-Woodward Soils.

L_7 - Land Productivity Class VII. Rough and severely eroded upland range. Considerable lower and wider range in carrying capacity than L_6.

APPENDIX TABLE II

ESTIMATED RELATIONSHIPS BETWEEN YIELDS, FERTILIZERS, AND IRRIGATION LEVELS, BY SOIL TYPE, AND BELOW AVERAGE RAINFALL

Crop and Levels of Irrigation	Fertilizer N	Fertilizer P	Unit	Average Rainfall L_1 Land	Average Rainfall L_2 Land	Below Average Rainfall L_1 Land	Below Average Rainfall L_2 Land
	Lbs.	Lbs.		Yields Per Acre			
Cotton							
I_0	26	0	lbs. lint	290	257	207	184
I_1	57	30	"	490	430	490	430
I_2	57	30	"	620	550	620	550
I_3	57	30	"	725	650	725	650
Wheat							
I_0	16	0	bu.	22.00	18.00	14.00	11.00
I_1	25	23	"	29.00	24.00	29.00	24.00
I_2	25	23	"	36.00	32.00	36.00	32.00
I_3	25	23	"	41.00	37.00	41.00	37.00
Alfalfa							
I_0	0	0	ton	2.60	2.00	1.90	1.40
I_1	0	68	"	4.30	3.20	4.30	3.20
I_2	0	68	"	5.50	4.20	5.50	4.20
I_3	0	68	"	6.40	5.00	6.40	5.00
Grain Sorghum							
I_0	0	0	cwt.	21.00	16.50	13.30	10.50
I_1	33	23	"	36.00	29.25	36.00	29.25
I_2	33	23	"	39.50	31.75	39.50	31.75
I_3	33	23	"	41.00	33.00	41.00	33.00
Forage Sorghum							
I_0	0	0	ton	2.80	2.20	1.80	1.40
I_1	25	0	"	8.50	7.00	8.50	7.00
I_2	25	0	"	11.80	9.30	11.80	9.30
I_3	25	0	"	14.00	11.00	14.00	11.00
Bermuda							
I_0	0	0	AUM	4.00	3.50	2.00	1.50
I_1	200	0	"	16.00	13.00	16.00	13.00

APPENDIX TABLE III

ACRES IRRIGATED PER FARM BY FARM RESOURCE SITUATION, FARM IRRIGATION LEVEL, AND RAINFALL CONDITIONS

Farm Resource Situation	Number of Farms in Population	Average Rainfall Farm Water Levels			Below Average Rainfall Farm Water Levels		
		2	3	4	2	3	4
			- Acres -			- Acres -	
A-1	23	12	26	38	12	38	38
B-1	25	26	57	85	30	85	85
C-1	12	20	44	65	23	65	65
C-2	16	22	42	65	22	49	65
D-1	21	68	120	163	95	144	163
D-2	7	52	104	163	53	115	163
E-1	16	34	73	112	47	112	112
E-2	7	34	72	112	39	87	112
F-1	18	92	190	302	184	289	302
F-2	5	100	209	302	155	290	302
Totals for County	150	6,248	8,779	12,608	9,132	17,445	18,905